Division's May Exhibit 23

APPENDIX 4.5-B

GEOMORPHOLOGY AND SEDIMENTOLOGY OF SINK VALLEY, KANE COUNTY, UTAH

Report to Utah International, Inc.

Alton Coal Project

by

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APPENDIX 4.5-B

GEOMORPHOLOGY AND SEDIMENTOLOGY OF SINK VALLEY

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GEOMORPHOLOGY AND SEDIMENTOLOGY OF SINK VALLEY

INTRODUCTION

Sink Valley is located in the West Panel of the Alton Coal Project. Discharge from the valley is carried by Sink Valley Wash to Kanab Creek. The confluence of these two drainages is located south of the West Panel boundary. The current status of Sink Valley Wash cannot be discussed in isolation from Kanab Creek. Kanab Creek is an incised channel (Schumm et al., 1984), and as such, it has lowered base level for Sink Valley Wash. Sink Valley Wash has degraded (incised) in response to the base level lowering. The magnitude of the degradation and the degradation-induced widening (Harvey and Watson, 1986) can be determined by comparing the General Land office surveyor's description of Sink Creek (his term for Sink Valley Wash, approximate location 2 miles downstream of road culvert (T40S, R5W, S5, NW1/4, NW1/4) on Alton - Skutumpah Road, (County Road 136)) with the present condition of the channel downstream of the culvert. Burrill (1876) described Sink Creek as being 5 links (about 3 feet) wide and 6 inches deep. In contrast, Sink Valley Wash is now 69 feet wide and 23 feet deep. The culvert is currently preventing the incision from migrating upstream into the main portion of Sink Valley.

The degradation of Kanab Creek may have influenced the capture, by Lower Robinson Creek, of the majority of the discharge from the upper basin of Sink Valley. The capture has reduced the generally unconcentrated flows that currently drain through the middle and lower portions of Sink Valley.

Historical accounts indicate that part of the Alton-Skutumpah Road was located within Sink Valley, and that the valley was so named because the wagons of the early settlers would sink into the clay during wet periods (Carroll, 1960). Gregory (1935) describes the area as being swampy in his field notes. Local landowners (Messrs. Johnson and Sorenson) report that upstream of the culvert the incised channel within which a number of dams have been built, was caused by runoff down the old Alton-Skutumpah road.

ALLUVIAL VALLEY FLOOR DEFINITION

Clarification of the definition of an alluvial valley floor is provided in the Office of Surface Mining's (OSMRE, 1983), draft Alluvial Valley Floor Identification and Study Guidelines. Two sets of criteria (1) Geologic and (2) Water Availability are presented. The geologic criteria are:

a. a topographic valley with a continuous perennial, intermittent, or ephemeral stream channel running through it; and

b. within that valley, those surface landforms that are either flood plains or terraces if these landforms are underlain by unconsolidated deposits (streamlaid); and

c. within that valley, those side-slope areas that can reasonably be shown to be underlain by alluvium and which are adjacent to flood plain or terrace landform areas.

Specifically excluded from the OSM definition of alluvial valley floors are upland areas, which are defined as those geomorphic features located outside the flood plain and terrace complex, such as isolated higher terraces, alluvial fans, pediment surfaces, landslide deposits, and surfaces covered with residuum, mud flows or debris flows, as well as highland areas underlain by bedrock and covered by residual weathered material or debris deposited by sheetwash, rillwash, or windblown material.

Current regulations of the Utah Division of Oil, Gas and Mining state that unconsolidated streamlaid deposits holding streams means, with respect to alluvial valley floors, all floodplains and terraces located in the lower portions of topographic valleys which contain perennial or other streams with channels that are greater than 3 feet in bankfull width and greater than 0.5 feet in bankfull depth.

On the basis of the geologic criteria it is apparent, therefore, that the requirement for an Alluvial Valley Floor determination is the presence of a continuous channel within a topographic valley, the floor of which contains floodplain and terrace features that are underlain by unconsolidated streamlaid deposits. The flow regime of the channel may be perennial, intermittent or ephemeral. By the same criterion,, alluvial fans, areas underlain by bedrock and covered by mud flows, debris flows or sheetwash deposits are not considered to be alluvial valley floors.

LANDFORMS IN SINK VALLEY

Upstream of the aforementioned culvert on County Road 136 (Alton-Skutumpah), the landforms within Sink Valley are composed of (1) landslide and debris flow deposits, (2) tributary alluvial fans, (3) a large valley fan, (4) a valley floor, and (5) Tropic Shale outcrops and bedrock surfaces mantled with a veneer of weathered Tropic Shale and colluvium. Landslide and debris flow deposits are part of the Swapp Hollow tributary alluvial fan.

(1) Landslide and Debris Flow Deposits

Significant landslide deposits are present on the southern margin of Swapp Hollow valley, the result of mass failure of a higher elevation dissected pediment that had been formed on the Tropic Shale. The landslide deposits are located on the surface of the Swapp Hollow tributary alluvial fan; they can be delineated by the hummocky topography they form and by the presence of scrub oak vegetation. Debris flow deposits have also formed hummocky topography to the south of Swapp Hollow on the eastern flank of Sink Valley (Exhibit 4.5-B1) and to the south of Lower Robinson Creek, east of the low relief, linear Tropic Shale ridge. The extent of the debris flow deposits and the hummocky topography is indicated by the presence of scrub oak.

Mass failures within the Tropic Shale are located on both the western and eastern margins of upper Sink Valley and the failed materials are characterized by hummocky topography. More recent mass failures within the Tropic Shale are located on the north side of Lower Robinson Creek outside the margins of the valley. The source areas for the failed materials are recognizable by the presence of crescentic scarps on the valley margins. It is apparent that mass wasting has been, and still is, a significant process with respect to the geomorphic development of Sink Valley. It is, therefore, logical to conclude that materials emplaced within the valley fill by mass wasting processes make up a significant part of the valley fill.

Therefore, on the basis of the geologic criteria contained within the regulatory definition of an alluvial valley floor, those areas within Sink Valley that are composed of landslide and debris flows are not classified as an alluvial valley floor.

(2) Tributary Alluvial Fans

Three major tributary alluvial fans are located on the eastern margin of Sink Valley. They are from north to south (1) Water Canyon fan, (2) Unnamed fan in Section 21 and, (3) Swapp Hollow fan. The fans have built out onto the floor of Sink Valley and in general their downstream terminii can be recognized by a break in slope (Schumm et al; 1987). Sediments delivered by the fans to Sink Valley are characteristic of the rocks in their watersheds. On the Water Canyon fan clasts derived from Wasatch Formation, Straightcliffs Sandstone and the Tropic Shale were observed. In the Unnamed fan (Section 21) watershed, there is no outcrop of Wasatch Formation, and therefore, the fan sediments are derived from Straightcliffs Sandstone and Tropic Shale. Clasts derived from Wasatch Formation, Straightcliffs Sandstone and Tropic Shale were observed on the Swapp Hollow fan. Furthermore, pediment gravels that are composed primarily of quartzite, and limestone clasts, which originated from a basal conglomerate in the lower Wasatch Formation, were observed on the Swapp Hollow Fan. These gravels were probably delivered to the fan by failure of the Tropic Shale outcrop that forms the southern margin of the Swapp Hollow valley.

Matrix-supported gravels and cobbles were observed in the banks of discontinuous gullies at various locations on the Swapp Hollow fan; they indicate that debris-flow deposition has occurred on the fan. Fine-grained Tropic Shale-derived sediments appear to dominate in the banks of the discontinuous gullies on both Swapp Hollow and the Unnamed (Section 21) fans. These sediments show no primary sedimentary structures internally, and this presents a problem with respect to determining their mode of deposition. The lack of sorting and internal organization is due to the uniform size of these fine-grained sediments. However, the scientific literature on alluvial fans indicates that arid and semi-arid region fans should be composed of a high proportion of mudflow and debris-flow deposits (Beaty, 1970). Other investigators have suggested that the fans should be composed of varying proportions of mudflow and streamflow deposits (Bull, 1964a; Wasson, 1977; Harvey, 1984b). Beaty (1974) has argued that in semi-arid areas chance catastrophic discharges are very important in the development of mudflows and debris flows. Since the tributary fans are located in a semi-arid area, where local and intense thunderstorm activity is common, and there is a source of fine-grained materials (Hampton, 1975; Harvey 1974), it is highly likely that deposition on the fans is dominated by mudflows and debris flows. Some sheetflood reworking of the primary mudflow and debris flow deposits is likely to occur during recessional portions of the events (Schumm et al., 1987).

The likelihood that sedimentation on the fans is dominated by debris-and mud-flows is supported by the absence of continuous channels on the fans (Exhibit 4.5-B1). Discontinuous channels that form on locally oversteepened reaches of alluvial fans are characteristic of all alluvial fans (Harvey, 1984; Schumm et al., 1987).

Alluvial fans are specifically excluded from the regulatory definition of an alluvial valley floor and, therefore, the tributary alluvial fans in Sink Valley are not considered to represent part of an alluvial valley floor.

(3) Valley Fan

In contrast to tributary alluvial fans, the floors of valleys in the semi-arid regions of the western U.S. can be comprised of valley alluvial fans (Patton, 1973; Patton and Schumm, 1975; Bergstrom and Schumm, 1981; Harvey, 1980; Schumm and Hadley, 1957; Laird and Harvey, 1986). In these valleys, the flat-appearing floors are irregular in the downstream direction. The irregularities represent convex reaches where sediment is stored, and they frequently occur at or downstream from tributary junctions. Within one valley, there may be numerous such convexities. As the convexities are formed, the valley floor is steepened locally, and eventually discontinuous gullies form. The discontinuous gullies move sediment down-valley, and the sediment is deposited as smaller fans within the valley where the flow becomes unconfined by the gully walls. Schumm et al. (1987) demonstrated experimentally that the irregular longitudinal profile found on many fans could be generated by both fluvial and mixed-mode (i.e., mudflow dominated) processes. Harvey (1984b) suggested that debris flow-dominated fans are more likely to have numerous disconnected channel segments because of the greater irregularity of the fan surface.

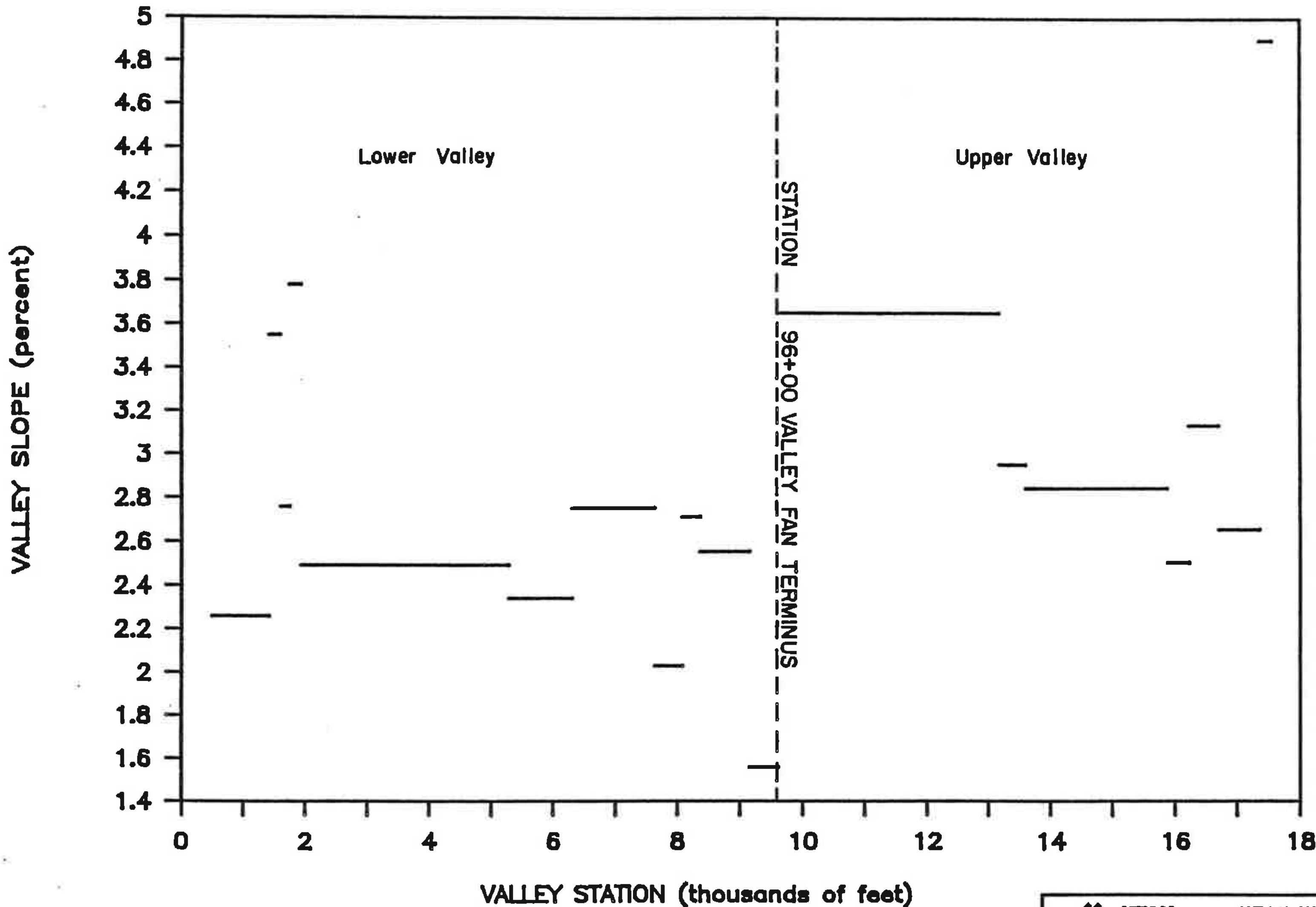
From the above discussion it is clear that fan sedimentology has important implications for understanding fan morphology, and this is especially true with respect to areas of aggradation and degradation (i.e., gullying). It is also important to note that fans are not restricted to the smaller drainage basins, but in the semi-arid areas of the western U.S., a type of fan exists that is a valley fan. The processes that operate on the valley fans are very similar to those that have been described for the classical alluvial fans in semi-arid areas (Bull, 1964a, b; Denny, 1965; Hooke, 1967, 1968a; Lustig, 1965).

The first indication that the valley floor of Sink Valley might be a valley fan can be seen on the 7.5 min. USGS quandrangle (Alton, Kane County Utah). The 40-foot contour-interval map suggests that a fan-shaped body has prograded down valley from the upper part of the Lower Robinson Creek drainage. Field inspection of the area suggested that the contours did not exactly represent the situation because of the contour interval. As a result a longitudinal profile of the valley floor was surveyed with an electronic-distance-meter-coupled theodolite. The longitudinal profile was started 500 feet downstream of the culvert on the Alton-Skutumpah road, and was continued up the center line of the valley for a distance of 17,550 feet (Exhibits 4.5-B2 and 4.5-B3; longitudinal section A-A'). Four cross sections of the valley were also surveyed (Exhibits 4.5-B4, cross sections a-a' and b-b'; and 4.5-B5, cross sections c-c' and d-d'). Vertical control for the survey was provided by a previously established elevation at Well Y98 (Al) (7172.6 ft.) Horizontal distances were established with a Hip Chain that was calibrated in feet.

The longitudinal profile of the Sink Valley floor exhibits numerous irregularities that represent local convexities (Schumm and Hadley, 1957; Patton and Schumm, 1976). A major change in slope on the profile is located at Station 96+00 (i.e., 9600 ft up-valley from origin of survey), which coincides with a field observed change in slope and character of the valley floor. This location is just north of the Sorenson ranch buildings, and represents the down-valley terminus of the major valley fan. The segmented nature of the entire valley floor is apparent from the plotted longitudinal profile. The slopes of the 18 individual segments that were defined by breaks in the profile were computed from the county road culvert to the up-valley end of the survey (Well Y98 (A1)). The data show that the valley floor slope is very irregular, with flatter segments alternating with steeper segments (Exhibits 4.5-B6 and 4.5-B7). The valley floor profile can be divided into two sections, Upper Sink Valley (Station 96+00 to 175+50), and Lower Sink Valley (Station 4+90 to 96+00). The mean slope and standard deviation for the two very different sections of the profile were computed; they are 0.0261 ± 0.0063 and 0.0323 ± 0.0082 for the lower and upper sections, respectively. A t-test of the mean values for the two sections ($\alpha = 0.1$) showed that the mean slopes for the two sections were different statistically.

The valley slope data suggest two things. First, the upper and lower sections of the valley are two different entities and second, there is a great deal of irregularity in the profile of each valley section. When taken together the two factors strongly suggest that the formation of the valley floor of Sink Valley was not the result of normal fluvial system behavior. In other words, a continuous channel did not build a valley floor floodplain by the processes of lateral and vertical accretion (Wolman and Leopold, 1957).

SINK VALLEY WASH



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550 California Street, San Francisco, Ca. 94104

ALTON COAL PROJECT

Valley Slope by Valley Station
Sink Valley Longitudinal Profile
(Exhibit 4.5-B2 & B3)

Water Engineering & Technology Inc.

DRAWN BY	DATE	SCALE	EXHIBIT NO.
APPROVED BY		DRG. NO.	4.5-B6

EXHIBIT 4.5-B7

VALLEY SLOPE DATA FROM SURVEYED LONGITUDINAL PROFILE OF SINK VALLEY

Station (ft)	Station (ft)	Valley Slope (ft/ft)
4+90	14+12	0.0226
14+12	15+95	0.0355
15+95	17+40	0.0276
17+40	19+25	0.0378
19+25	52+75	0.0249
52+75	63+00	0.0234
63+00	76+27	0.0275
76+27	80+70	0.0203
80+70	83+65	0.0271
83+65	91+50	0.0255
91+50	96+00	0.0156
96+00	131+70	0.0365
131+70	135+90	0.0295
135+90	158+70	0.0284
158+70	162+20	0.0250
162+20	167+00	0.0313
167+00	173+50	0.0265
173+50	175+50	0.0490

If the above statement is true, then it is necessary to determine the processes that are responsible for the valley floor irregularities.

The irregularity of the upper section (Stations 96+00 to 175+50) can be explained in terms of alluvial fan dynamics. The upper portion of Sink Valley is fed by a number of tributaries; Dry Fork, Water Canyon, and a number of unnamed tributaries. Tributary alluvial fans have built out onto the floor of the valley, and as discussed previously, the fan sediments appear to be dominated by debris flows and mudflows. The width of Upper Sink Valley is greater than the widths of the individual tributary valleys. Therefore, during tributary events (Thornes, 1977), deposition is likely to occur on the floor of Upper Sink Valley. The deposition on the valley floor leads to an accumulation of sediments at the tributary mouths (Schumm et al., 1987). During a major event in the valley (i.e., axial event; Thorne, 1977) this sediment can then be transported down valley, as a result of debris flows and unconfined sheet flows. Since the valley widens in the down-valley direction, deposition is likely to occur progressively down-valley and will result in a great deal of topographic irregularity.

This scenario is supported by a number of factors. The normal grain-size relationships on the surface of alluvial fans is one of decreasing grain-size downfan (Blissenbach, 1954; Bull, 1964b; Rust and Koster, 1984). However, field observations in Sink Valley indicated that coarse-grained clasts were present over much of the surface of the upper section especially in the area of the hummocky topography that is located south of Lower Robinson Creek. The association of the coarse clasts and the hummocky topography strongly suggests that debris flows were responsible for the down fan delivery of the clasts (Schumm et al. 1987). The source area for the coarser clasts was the upper part of Sink Valley because the clasts are derived from Wasatch Formation and there is no local source on the north side of Lower Robinson Creek. The inverse grading of the sediments on the fan surface could also be due to another mechanism, fan-head trenching (Schumm et al., 1987), which allows coarser sediments to bypass the fan apex and to be deposited down-fan. The development of a fan-head trench is the result of aggradation at the fan-head, which causes the fan slope to be oversteepened until incision begins (Schumm, 1977). The cycle of fan-head trenching and back-filling of the trench is more common on fluvially dominated fans than it is on mudflow or mixed-mode fans (Schumm et al., 1987), but it cannot be discounted in upper Sink Valley because fluvially deposited sediments were observed in the banks of the incised portion of Lower Robinson Creek within the upper part of Sink Valley.

That the upper part of Sink Valley is composed of a valley fan is supported by the absence of a continuous channel. The channel segments observable on color aerial photos of Sink Valley were mapped from the photos, and then the map was field checked (Exhibit 4.5-B1). In the upper part of the valley there are a series of discontinuous gully segments as well as channel segments that have been dug for irrigation purposes. Two deeply incised channels that are parallel run along the western margin of the valley, and they have both been captured by Lower Robinson Creek. The fact that the channels are parallel and straight suggest that they have been influenced significantly by human activities. This is further supported by two parallel channels that appear to be continuations of the incised channels and that disappear in the mid-fan region. These two channels have been beheaded by the incision of Lower Robinson Creek. Data were not available to ascertain whether a channel existed in the floor of upper Sink Valley prior to the capture of this area by Lower Robinson Creek. A network of discontinuous gullies is located on the eastern margin of the valley floor in the vicinity of the location of the unnamed tributary fan. The gullies have probably formed as a result of local oversteepening of that part of the fan, as a result of tributary sediment contribution

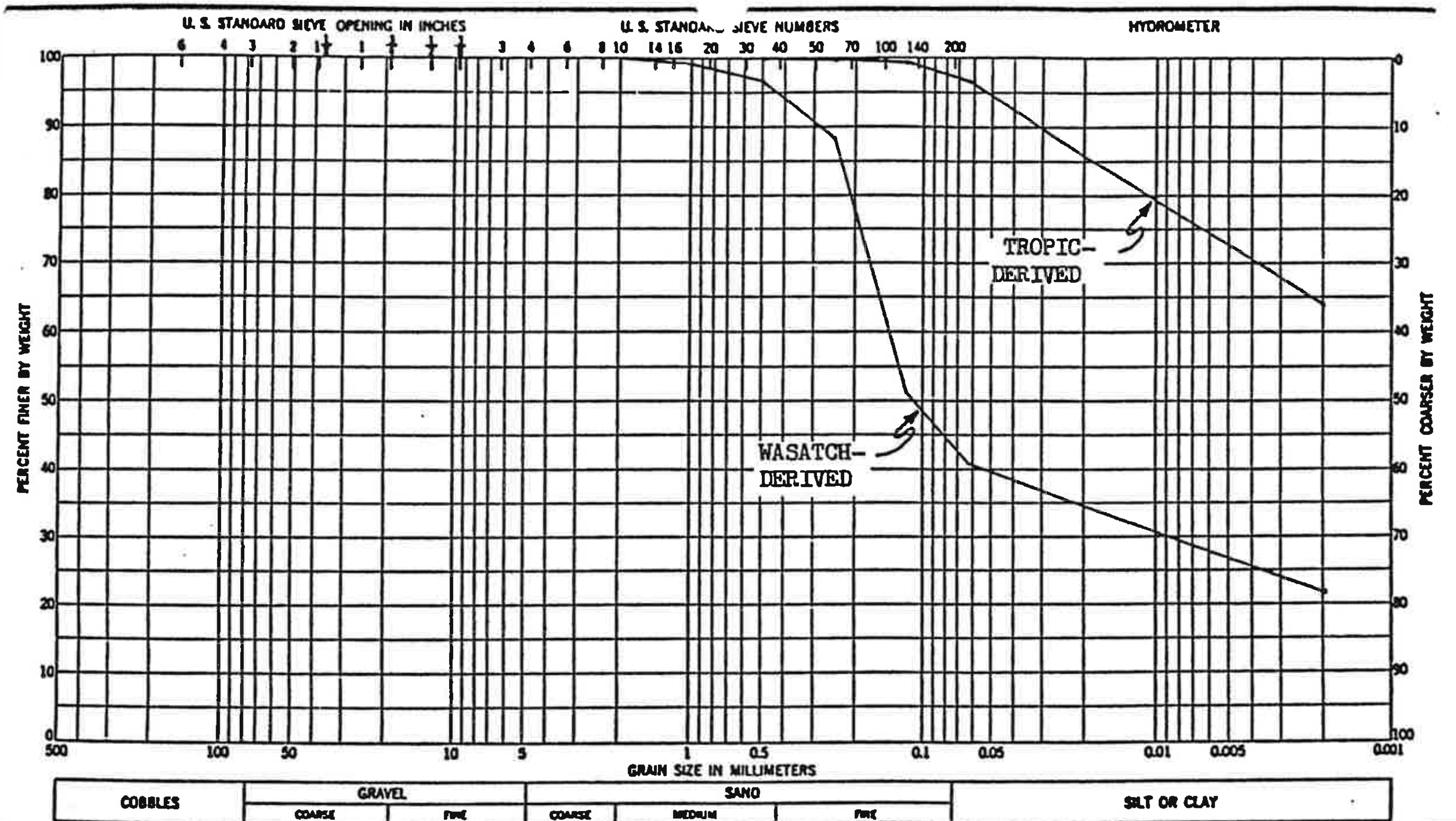
(Schumm and Hadley, 1957). Four small dams have been emplaced in the incised channel. Mr. Sorensen reports that the incised channel was artificially lengthened in the down-valley direction in order to convey irrigation water farther down valley toward the mouth of Swapp Hollow. Water was conveyed progressively downstream through a series of small dams and excavated channels (Exhibit 4.5-B1). Cross sections c to c′ and d to d′ (Exhibit 4.5-B5) show the distribution of the channel segments in the upper and mid-fan regions. The cross sections span the valley floor.

Further evidence for the valley fan is contained in the banks of Lower Robinson Creek, which has incised to a depth of about 40 feet. Exposed in the banks of the channel is the stratigraphic fill on the western margin of the fan. The basal portion of the fill is made up exclusively of Tropic Shale-derived sediments. These sediments, which are very fine grained, were derived from the Tropic Shale outcrop on the north side of Lower Robinson Creek. The general lack of a range of grain sizes in this sediment makes it almost impossible to determine either the paleo-flow direction or the nature of the transport mechanism for the sediments. However, the nature and orientation of the contact between the basal Tropic Shale-derived sediments and the overlying sediments that are derived from the Wasatch Formation does provide information on paleo-flow direction.

Without doubt the Tropic Shale outcrop that forms the valley wall on the north side of Lower Robinson Creek is retreating today as a result of both mass wasting and sheet erosion processes, and there is no reason to believe that these processes were not active historically. Prior to the incision of Lower Robinson Creek, channelized flow occurred from the Tropic Shale outcrop, across what is now Lower Robinson Creek, and southward into Sink Valley. Evidence for this is channel-shaped scour surfaces within the Tropic Shale basal sediments exposed in the banks of Lower Robinson Creek. The scour surfaces are oriented perpendicular to the present channel of lower Robinson Creek. The scoured channels have been filled by sediments derived from the Wasatch Formation. Since there is no source of Wasatch Formation sediments on the north side of Lower Robinson Creek, the paleo-flow direction of the Wasatch Formation sediments must have been parallel or sub-parallel to the present course of Lower Robinson Creek.

The Wasatch Formation sediments that are exposed in the upper part of the channel banks of Lower Robinson Creek exhibit a fining trend in the downstream direction, with boulder to cobble sized sediments being present in the upstream exposures and coarse sand to clay sized sediments being present in the downstream exposures. Examples of the grain size distributions of the lower, Tropic Shale sediments and the upper, Wasatch Formation sediments, that were collected at the same location along Lower Robinson Creek (i.e. T39S, R5W, S20, NE1/4, SW1/4, SW1/4; near the fence line crossing the road that parallels Lower Robinson Creek) are shown in Exhibit 4.5-B8. It is obvious from the plotted distributions that the two materials have very different grain sizes. Further, there is a distinct color difference between the two. Tropic Shale sediments are olive-grey-brown in color (10YR 3/2 to 10YR 4/4) whereas the Wasatch Formation sediments are tan-red-brown in color (10YR 5/4 to 10YR 5/8).

The ease with which the sediments from the two source areas can be differentiated enables the down-valley building of the fan margin to be documented. Lower Robinson Creek in its present location marks the boundary between the valley-wall supplied area and the margin of the valley fan that has prograded towards the linear Tropic Shale ridge on the south side of Lower Robinson Creek (Exhibit 4.5-B1). Evidence for this is the distribution of the Wasatch Formation sediments that form the upper part of the valley fill. Upstream of where Lower Robinson Creek flanks the linear Tropic Shale ridge, Wasatch Formation sediments are located only on the true left bank (i.e., left bank looking downstream). However, downstream



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI
	--					

Project Alton Coal Project
Sediment Sample Site #1
Area Lower Robinson Creek
Boring No.
Date May 1987

GRADATION CURVES

ENG FORM 1 MAY 63 2087

UTAH International
UTAH INTERNATIONAL INC.
550 California Street, San Francisco, Ca. 94104

ALTON COAL PROJECT

Grain Size Distribution Curves for Lower Robinson Creek Sediments

DRAWN BY	DATE	SCALE	EXHIBIT NO.
APPROVED BY		DRG. NO.	4.5-B8

of the ridge these sediments form a thin veneer on the surface of the true right bank as well. This suggests that the fan prograded down-valley until unconfined fan flows overtopped the Tropic Shale ridge, at which point, the sediment-carrying flows were diverted to the right bank area, and they were distributed into the Lower Robinson Creek drainage basin. Wasatch Formation sediments were observed also to form a veneer on top of the Tropic Shale sediments to the west and southwest of the Tropic Shale ridge. Since there was no source area for the Wasatch Formation sediments in the Lower Robinson Creek drainage basin prior to capture of the flow from upper Sink Valley, then the deposition of these sediments must have predated the capture. As will be discussed later, progradation of the fan and overtopping of the Tropic Shale ridge may have been responsible, in part, for the capture.

In summary, the upper section of Sink Valley is composed of a valley fan. The irregularity of the slopes of various segments of the longitudinal profile, the presence of inverse-grading of the sediments on the fan surface, the hummocky terrain, the absence of a continuous channel, and the sedimentologic observations from the banks of Lower Robinson Creek all support this interpretation. Since the upper section of Sink Valley is composed of a valley fan not adjacent to a floodplain/terrace complex it does not fall within the regulatory definition of an alluvial valley floor.

(4) Valley Floor

The valley floor of the lower section of Sink Valley (Stations 4+90 to 96+00) also has a highly irregular longitudinal profile (Exhibits 4.5-B2 and 4.5-B3), but it is obviously not part of the large valley fan in the upper section of Sink Valley. As previously stated, the irregularity of the valley floor is not compatible with a purely fluvial origin and, therefore, different processes must be involved. The reasons for the valley floor irregularity are probably multiple, and among the more significant are likely to be, (1) tributary contribution of mudflow, debris-flow and sheet-flood sediments from Swapp Hollow, (2) sheet flood and possibly mudflow transported sediments delivered to the lower section of the valley (the valley floor) from the upper section valley fan, (3) sediments derived from discontinuous gullies on the valley fans (4) colluvial sediments transported from the eastern and western valley walls (Tropic Shale outcrops) by sheet flow and flows confined within hillside gullies, and (5) trenching of locally oversteepened sections of the valley floor and down-valley distribution of the sediments derived from the trenches.

A high density of channel segments exists on the valley floor within this lower portion of Sink Valley (Exhibit 4.5-B1). However, it is apparent that many of the discontinuous channel segments are anthropogenic in origin, and their locations are such that they were used to spread flows for surface irrigation. Without doubt the lower portion of the valley floor has incised at some time in the recent past. The local landowners report that the incised channel follows the alignment of the wagon road that ran from Alton to Skutumpah. It is not clear whether the incision was due only to the presence of the wagon ruts or whether it was due to a combination of factors that involved the base level lowering of Sink Valley Wash. Regardless of the origin of the incised channel, it now contains several small dams. A number of small channels emanate from the dams and convey irrigation water to the valley floor. Further there are a number of small gullies that have formed in response to base level lowering in the incised reach.

The valley floor sediments that are exposed in the bends and banks of the discontinuous gullies and channel segments are derived from a number of lithologies. The coarsest sediments (cobbles and gravels) appear to have been derived from basal conglomerate of the Wasatch Formation, and it is likely that their immediate source area was the pediment surface on the eastern margin of the valley. Wasatch Formation sediments that are finer grained could have been delivered to the valley floor from Swapp Hollow or from upper Sink Valley. Tropic Shale sediments could have been delivered from the valley margins and Swapp Hollow. The primary sedimentary structure that was most commonly observed in the sand-sized Wasatch Formation sediments was horizontal stratification. This form of stratification can be produced by two different hydrologic/hydraulic conditions: (1) upperflow regime channelized flow (Simons and Richardson, 1966) and, (2) unconfined sheet flow (McKee et al., 1967). Since there are no well defined channels within the valley floor, the later mechanism is probably responsible for the formation of the horizontal stratification. Valley-wide sheetflooding was reported to have occurred in lower Sink Valley during 1983.

Two cross sections were surveyed across the valley in the lower section (Exhibit 4.5-B3; a to a′, b to b′). Cross section a - a′ indicates that no channel exists in the valley floor at this location, except for the former wagon road incised channel, which is located on the western margin of the valley next to an outcrop of clinker. The cross section was chosen to represent a very narrow section of the valley because the probability of having a channel in this narrow section is high. Cross section b - b′ shows that the cross-valley profile is very different from a normal cross-valley profile. A discontinuous channel segment is located about 860 ft. from the eastern valley wall on a relatively high part of the valley floor. The cross profile of the valley loses elevation to the west where it intersects the wagon-road incised channel. A discontinuous gully is located at the western end of the cross section. The higher density of channels on the western end of the cross section is the result of drainage from the low relief, Tropic Shale that underlies the western margin of the valley. A veneer of Wasatch Formation derived silts and sands was observed to mantle the valley floor in the general location of the old wagon road, and the sediments were probably deposited by recent sheet flooding.

Classification of the lower section (Stations 4+90 to 96+00) of Sink Valley is not as easy as it was for the upper section because the valley floor has been substantially modified as a result of irrigation practices and gully erosion. The irregularity of the longitudinal profile, the absence of a continuous channel, and the limited sedimentological data suggest that the valley floor surface is composed of a series of small valley fans. Therefore, the valley floor in the lower section of Sink Valley does not meet the regulatory geologic criteria for an alluvial valley floor.

(5) Tropic Shale Outcrops

The gross morphology of Sink Valley is controlled by the relative resistance to erosion of the lithologies that make up the basin boundaries. The narrow, lower portion of the valley is controlled by more resistant outcrops of Dakota Sandstone. Where the valley widens the basin boundaries are composed of Tropic Shale which is less resistant. The topography of those parts of the basin boundary that are composed of Tropic Shale is dependent on the presence or absence of either overlying sandstone or pediment gravels.

The western margin of the basin (Exhibit 4.5-B1), which more or less parallels the Alton-Skutumpah road, is a relatively gently sloping, low relief divide. The Tropic Shale is not capped by either sandstone or pediment gravels. Retreat of the shale has produced a small basin that extends from about the Swapp ranch to the Sorenson ranch road, and it has the appearance of an amphitheater.

The linear ridge of Tropic Shale that extends northwards from about Swapp ranch to Lower Robinson Creek forms the divide between Sink Valley and the southern part of the Lower Robinson Creek drainage basins. It probably represents a dissected pediment surface reminant. The pediment was graded to the Tropic Shale outcrop that forms the basin boundary on the north side of Lower Robinson Creek. Rejuvenation of the Lower Robinson Creek basin due to base level lowering in Kanab Creek has resulted in an increased drainage density on the western side of the drainage divide. Drill hole information suggest that the sub-crop profile of the Tropic Shale on the eastern side of the divide is very similar to that exposed at the surface on the western side of the divide. This suggests that historically the Tropic Shale remnant was retreating both to the east and to the west until the eastern margin was buried by valley fan deposition that was prograding down valley from Upper Sink Valley.

On the north side of Lower Robinson Creek the Tropic Shale is capped by a poorly cemented sandstone, and as a result, the basin boundary is considerably steeper and has greater relief. The basin boundary is retreating, as a result of deep seated mass failure of the Tropic Shale. Similar types of failures are occurring, or have occurred, on the western and eastern margins of Upper Sink Valley.

Pediment gravels cap the Tropic Shale that forms the eastern margin of the middle reach of Sink Valley in the general location of Swapp Hollow. Retreat of the basin boundary is due to both mass movement failures which produces steep crescentic shaped slopes, and sheet erosion that produces more gentle slopes. At the mouth of Swapp Hollow, there are three relatively low relief outcrops of Tropic Shale. They are capped by pediment gravels, and they may represent the dissected remnants of a former pediment surface.

Within Sink Valley, bedrock surfaces that are mantled with residuum and colluvium occur on the low-relief western margin of the valley between the entrance to the Sorenson ranch at the county road and Swapp ranch (Exhibit 4.5-B1). This area probably can be classified as a low-relief pediment surface. The Tropic Shale bedrock is overlain by a thin veneer of in situ weathered shale and sheetwash deposits. Drill hole Y-72-C and Y-38-C are located on the pediment surface and the lithologic logs confirm the above interpretation.

The regulatory definition of an alluvial valley floor specifically excludes pediment surfaces, surfaces covered by venidium and upland areas underlain by bedrock and covered by residual weathered material. Therefore, the locations within Sink Valley that are discussed in this section fail to meet the alluvial valley floor geologic criteria.

ARTESIAN CONDITIONS IN SINK VALLEY

A number of shallow artesian water wells are located in the middle portion of Sink Valley in the general locations of the Sorenson and Swapp ranches. An artesian condition in a valley floor is unusual, and its presence argues for sub-surface conditions that are atypical of a normal valley fill that is composed primarily of fluvially deposited sediments. The artesian condition indicates that a confined aquifer must be present at some depth below the ground surface, and that the confining layer is likely to be composed of silt and clay-sized sediments. As previously discussed, there are a number of sources of silt and clay-sized sediments in the basin, Tropic Shale and Wasatch Formation. Exhibit 4.5-B7 indicates that the Tropic Shale sediments are composed of 97% silt and clay-sized particles and the finer component of the Wasatch Formation sediments are composed of 41% silt and clay-sized particles.

The composition of the valley-fill sediments in the general location of the artesian condition is obtained from the lithologic logs of holes drilled in this area, namely, Y-48(C), Y-24(C), and Y-62. A confining clay layer is present above a more permeable layer (sands and gravels) at depths that vary from 25 to 50 feet. If the gradient of the piezometric surface is approximately the same as that of the ground surface (Galloway et al., 1979), then sufficient head exists for the artesian condition.

The above explains why an artesian condition is present in the middle portion of Sink Valley, but the question that still remains to be addressed is why the condition exists in the valley floor at all. In other words, what sedimentological and geomorphological processes were responsible for the emplacement of the valley-fill units such that generation of an artesian condition was possible? Coincidentally, or otherwise, the location of the artesian condition is the same as the down-valley terminii of the valley fan and the Swapp Hollow tributary fan. Therefore, the artesian condition may be related to the depositional history of the fans.

Experimental (Schumm et al., 1987) and field studies (Rust and Koster, 1984) of alluvial fans have shown that grain size generally diminishes in the down-fan direction such that the distal portion of the fan at any time is composed of the finest sediments (i.e., silts and clays). Schumm et al. (1987) suggested that a sharp break in the slope profile near the toe of the fan marks the point at which the silts and clays are deposited. Deposition of the fines forms a clay-rich basal layer over which the fan progrades through time. Progradation of the fan results in coarser sediments being deposited over the basal layer and, therefore, at a given location on the fan the grain-size coarsens upwards. Coarsening upwards of sediment can also be the result of fan-head trenching, which delivers coarse sediment to the medial and distal parts of the fan. However, mud flows and debris flows are capable of traveling to the toe of the fan (Schumm et al., 1987); this process would cause deposition of a gravelly-clay to clay-rich layer over the more permeable sands and gravels that are deposited by the processes of normal fan progradation. The net result of this type of sedimentation pattern would be confined or semi-confined flow within the fan. Because of the nature of depositional processes on alluvial fans, depositional units are more continuous longitudinally than they are laterally (Schumm et al., 1987) and, therefore, it is likely that subsurface flows will tend to follow the depositional axis of the fan. Galloway et al. (1979) showed that on alluvial fans groundwater recharge on the upper fan surface takes place as a result of direct precipitation or infiltration of stream discharge. The groundwater is discharged in the lower fan region. However, if the lower fan region were to be covered by a confining layer of fine sediment then an artesian condition could develop near the toe of the fan.

The above discussion pertains to the artesian condition in Sink Valley. The artesian wells are located in the distal region of the valley fan, and as has been discussed previously, debris flows and mudflows are located on the fan. Further, the artesian wells are located opposite the mouth of Swapp Hollow, which could very well have produced sufficient fine material in the form of sheet-flows and mudflows, to seal the groundwater bearing sand and gravel units formed by progradation of the valley fan. Such conditions could well be responsible for the above-ground piezometric surface in Sink Valley. Groundwater recharge could be taking place in Upper Sink Valley and in the tributary alluvial fans on the eastern side of the valley.

GEOMORPHIC HISTORY OF LOWER ROBINSON CREEK

The recent geomorphic history of Lower Robinson Creek is significant to Sink Valley because capture of the upper part of Sink Valley by Lower Robinson Creek has reduced the flows discharging through the middle and lower parts of Sink Valley.

The timing of the capture is indeterminate but it is assumed to have occurred during the past 100 years. Possible mechanisms for inducing the capture are (1) base level lowering in Kanab Creek which is known to have occurred after settlement of the valley (see Section 4.1, Geomorphic Characterization), (2) overtopping of the Tropic Shale ridge which forms the divide between the Lower Robinson Creek basin and Sink Valley, as a result of progradation of the valley fan, and (3) human activity as evident by the unusually straight reach of lower Robinson Creek. It is possible that a combination of these mechanisms was responsible for the capture. If it is assumed that the capture took place after Kanab Creek degraded, then base level for Lower Robinson Creek would have been lowered and Lower Robinson Creek would have responded by degrading. The degradation would have involved headcutting in the bed, and the headcuts would have migrated upstream. Degradation generally predisposes channel widening, which in turn would have increased the channel capacity of Lower Robinson Creek. If at this time, a large flood had overtopped the Tropic Shale divide then the flow could have been retained within the enlarged channel of Lower Robinson Creek. The combination of increased channel capacity and very steep hydraulic gradient could have caused rapid headward migration of the channel and capture of the drainage from Sink Valley.

Some idea of the timing of the capture can be ascertained from the relationship between the current elevation of the bed of Lower Robinson Creek and the elevations of the beds of the parallel, man-modified channels that are located on the western margin of Upper Sink Valley which have been beheaded by the degradation of Lower Robinson Creek. If the parallel channels were in fact irrigation channels, then their construction must have pre-dated the capture, which suggests that the capture took place after settlement of Sink Valley, which took place in about 1865.

The capture by Lower Robinson Creek of the upper part of Sink Valley has captured the discharge from the headwaters of Sink Valley Wash. As a result of the degradation-induced channel widening, the capacity of the channel has increased to the point where it is highly unlikely that any flood flows will overtop the channel. Therefore, the incidence of flooding in the middle and lower parts of Sink Valley is likely to have been reduced significantly. This may be the reason why the headcuts, that are located in the lower part of Sink Valley upstream of the road culvert, appear to be migrating up-valley very slowly.

SUMMARY AND CONCLUSIONS

This study of Sink Valley was conducted to determine whether the valley floor met the regulatory geologic criteria to classify it as an alluvial valley floor. The landforms within Sink Valley are composed of 1) landslide and debris flow deposits, 2) tributary alluvial fans, 3) a large valley fan, 4) a valley floor, and 5) Tropic Shale outcrops and bedrock surfaces mantled with a veneer of weathered Tropic Shale and colluvium. The regulatory definition of an alluvial valley floor specifically exclude landslide and debris flow deposits and tributary alluvial fans from the definition of an alluvial valley floor.

Valley alluvial fans commonly occur in the valley floors of semi-arid regions of the western U.S. The upper section of the valley floor in Sink Valley (Station 96 + 00 to 175 + 50) is comprised of such a valley fan.

This interpretation is supported by the irregularity of the longitudinal profile, the presence of inverse-grading of the sediments on the fan surface, the hummocky terrain, the absence of a continuous channel, and the sedimentologic observations from the banks of Lower Robinson Creek. Therefore, the upper section of the valley floor in Sink Valley does not meet the regulatory geologic criteria for an alluvial valley floor.

The valley floor in the lower section of Sink Valley (Station 4 + 90 to 96 + 00) is composed of a series of small valley fans. This interpretation is supported by the irregularity of the longitudinal profile, the absence of a continuous channel, and the sedimentological data. The presence of an artesian condition in Sink Valley in the general locations of the Sorenson and Swapp ranches can be explained by alluvial fan dynamics. The presence of an artesian condition in Sink Valley argues against a purely fluvial origin for the valley fill since the fluvial processes of vertical and lateral accretion are unlikely to produce an artesian condition. For these reasons, and because of the absence of floodplains or terraces associated with USLD, this section of the valley floor of Sink Valley also does not meet the regulatory geologic criteria for an alluvial valley floor.

The Tropic Shale outcrops and bedrock surfaces mantled with a veneer of weathered Tropic Shale and colluvium are specifically excluded from this regulatory definition of an alluvial valley floor.

It may be concluded, therefore, that the landforms within Sink Valley do not constitute an alluvial valley floor as defined by the geologic criteria in the state regulatory definition and the draft OSMRE Alluvial Valley Floor Identification and Study Guidelines.

Capture by Lower Robinson Creek of the discharge from the headwaters of Sink Valley Wash appears to have occurred relatively recently (i.e., since 1865). The capture has reduced probably the incidence of flooding in the lower and middle parts of Sink Valley and it may be the reason why the headcuts, that are present upstream of the County Road 136 culvert, appear to be migrating up-valley very slowly.

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